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"On some Elementary Principles in Animal Mechanics."—No. II. By the Rev. SAMUEL HAUGHTON, M.D. Dublin, D.C.L. Oxon., Fellow of Trinity College, Dublin.

In a former communication to the Royal Society on this subject (Annals, October 1867, p. 294), I endeavoured to establish the two following principles:—

I. *That the force of a muscle is proportional to the area of its cross section.*

II. *That the force of a muscle is proportional to the cross section of the tendon that conveys its influence to a distant point.*

The first of these principles is true under all circumstances; but the second requires to be modified somewhat in its statement. If the conditions as to friction of the tendons that convey the action of the muscles to a distant point be the same, then the force of the muscles will be proportional to the cross sections of the tendons; but if the tendons be subjected to different amounts of friction, then the areas of their cross sections will cease to be proportional to the forces of the muscles as represented by the areas of their cross sections.

In my former paper (No. I.), I selected, in illustration of principle II., the long flexor tendons of the toes of the Rhea and other struthious birds, and showed that the cross sections of the muscles and tendons bore, approximately, a constant ratio to each other. Now, in the *Struthionidæ* the conditions as to friction of the long flexor tendons of the toes are similar, although different in each species; and hence it was easy to prove that the ratios of the cross sections of the muscles and tendons were nearly constant.

When, however, muscles and tendons, variously conditioned as to friction, are compared together, the constancy of the ratio of their cross sections disappears, and undergoes a variation depending on the friction to which both muscles and tendons are exposed.

In order to ascertain the proportion of the cross section (or force) of a muscle to the cross section (or strength) of its tendon in the human subject, I made the following observations on the right arm and hand of a well-developed male subject in the Royal College of Surgeons in Ireland, in March 1868.

I first ascertained the specific gravities of the muscles and tendons, with the following results:—

Muscles.

	Sp. gr.
Biceps humeri (*long head*)	1·050
Biceps humeri	1·054
Brachialis	1·053
Mean	1·0523

Tendons.

Scapular tendon of biceps	1·112
Radial tendon of biceps	1·119
Mean............	1·1155

From these specific gravities it was easy to determine the cross section of either muscles or tendons, by weighing a known length of either one or the other. In this manner the following Table was constructed :—

Cross sections of Muscles and Tendons in an Adult Human Male Subject, and Ratios of the same.

Name of muscle.	Cross section of muscle, in square inches.	Cross section of tendon, in square inches.	Ratio of cross section of muscle to that of tendon.
1. Biceps humeri	0·895	0·0317	28·2
2. Palmaris longus	0·148	0·0050	26·4
3. Ext. carp. rad. longior ...	0·584	0·0223	26·2
4. Ext. carp. rad. brevior ...	0·405	0·0220	18·4
5. Biceps humeri (long head)	0·379	0·0212	18·0
6. Fl. poll. longus	0·228	0·0145	15·7
7. Fl. carp. rad.	0·234	0·0155	15·1
8. Ext. carp. uln...............	0·212	0·0199	10·7
9. Fl. dig. subl.	0·618	0·0665	9·3
10. Fl. dig. prof.	0·768	0·0928	8·3
11. Ext. oss. met. poll.	0·223	0·0289	7·7
12. Fl. carp. uln.	0·182	0·0254	7·2

From the preceding Table, it appears that the ratio of the cross section of the muscles to that of the tendons may range from 7 to 28, or be four times as great in one case as in another. We may also see in general, that the tendons exposed to the greatest amount of friction have the smallest coefficients of cross section. Thus the radial tendon of the *biceps* has a coefficient of 28·2, while the scapular tendon, which undergoes the friction of passing over the head of the humerus, has a coefficient of 18·0. Again, the *Ext. oss. met. poll.*, whose tendon winds round the radius, and has the duty imposed upon it of binding down the tendons of the radial extensors of the wrist, has the coefficient of 7·7, as compared with 26·2 and 18·4, the coefficients of the comparatively free tendons of these extensors.

As it might be objected that the relative cross sections of muscle and tendon, in a human subject that died a natural death, might be exceptional in character, from wasting during the last illness, I determined to test the question by experiment, and accordingly selected a fine Pyrenean Mastiff for the purpose, which I killed by strychnia, and dissected immediately after death, with the following results, which were obtained, as before, by noting the specific gravities of the muscles and tendons, and by weighing a measured length of each :—

Cross sections of Muscles and Tendons in a Pyrenean Mastiff, and ratios of the same.

Name of muscle.	Cross section of muscle, in square inches.	Cross section of tendon, in square inches.	Ratio of cross section of muscle to that of tendon.
1. Gastrocnemius	2·631	0·0520	50·6
2. Fl. carp. rad.	0·283	0·0059	48·0
3. Fl. dig. long.	0·195	0·0045	43·3
4. Ext. carp. rad.	0·632	0·0160	39·5
5. Fl. carp. uln.	0·176	0·0056	31·4
6. Fl. hall. long.	0·680	0·0228	29·8
7. Biceps humeri	0·909	0·0449	20·2
8. Fl. dig. subl.	0·319	0·0251	12·7
9. Fl. dig. prof.	0·902	0·0830	10·9
10. Ext. carp. uln.	0·181	0·0197	9·2

These results, obtained from measurements made upon a freshly killed animal, confirm those found from observation of the human subject, and prove that the ratio of the cross section of the muscle to that of its tendon depends upon the amount of friction experienced by the latter, the coefficient being greater in proportion as the friction is less.

The following observations, made upon a Wallaby Kangaroo, confirm in a general way the preceding results :—

Cross sections of Muscles and Tendons in a Wallaby Kangaroo, and ratios of the same.

Name of muscle.	Cross section of muscle, in square inches.	Cross section of tendon, in square inches.	Ratio of cross section of muscle to that of tendon.
1. Gastrocnemius	1·313	0.0356	36·9
2. Fl. long. dig.	0·354	0·0246	14·4

It appears from the preceding investigation that the cross section of a muscle does not bear a constant ratio to the cross section of its tendon, unless the friction experienced by the muscle and tendon be also constant, and that there may even be a *surplusage* of strength in the tendon beyond what is absolutely necessary to resist the combined force of the muscle and friction. This surplusage, however, cannot be supposed to be large, if the principle of *economy of material* in nature be admitted.

"On *Holtenia*, a Genus of Vitreous Sponges." By Wyville Thomson, LL.D., F.R.S., Professor of Natural Science in Queen's College, Belfast.

During the deep-sea dredging cruise of H.M.S. 'Lightning' in the autumn of the year 1868, the dredge brought up, on the 6th of September, from a depth of 530 fathoms, in lat. 59° 36′ N., and long. 7° 20′ W., about 20 miles beyond the 100-fathom line of the Coast-Survey of Scotland, fine, grey, oozy mud, with forty or fifty entire examples of several species of siliceous sponges. The minimum temperature indicated by several registering thermometers was 47°·3 F., the surface-temperature for the several localities being 52°·5 F.

The mud brought up consisted chiefly of minute amorphous particles of carbonate of lime, with a considerable proportion of living *Globigerinæ* and other Foraminifera, and of the "coccoliths" and "coccospheres" so characteristic of the chalk-mud of the warmer area of the Atlantic. The sponges belonged to four genera: one of these was the genus *Hyalonema*, previously represented by the singular glass-rope sponges of Japan and the coast of Portugal; and the other three genera were new to science. One of these latter was the subject of the paper.

Associated with the sponges were representatives, usually of a small size, of the Mollusca, the Crustacea and Annelides, the Echinodermata, and the Cœlenterata, with numerous large and remarkable rhizopods. Many of the higher invertebrates were brightly coloured and had eyes.

Four nearly perfect specimens of the sponge described in the memoir were procured.

HOLTENIA, n. g.*

H. CARPENTERI, n. sp.

The body of the sponge is nearly globular or oval. Normal and apparently full-grown specimens are from 9″ to 1′ 1″ in length, and from 7″ to 9″ wide. The outer wall consists of an open, somewhat irregular, but very elegant network, whose skeleton is made up of large separate siliceous spicules. These spicules are formed on the sexradiate stellate type; but usually only five rays are developed, the sixth ray being represented by a tubercle. To form the framework of the external wall, the four secondary branches of the spicule spread on one plane, the surface of the sponge, while the fifth or azygous branch dips down into the sponge-substance. This arrangement of the spicules gives the outer surface of the sponge a distinctly stellate appearance, the centres of the stars being the point of radiation of the secondary branches of the spicules. These quinqueradiate spicules measure about 1″ 5‴ from point to point of the cross-like secondary branches; and the length of the azygous arm is from 7·5‴ to 1″.

Smaller stars, formed by the radiation of smaller spicules of the same class, occupy the spaces between the rays of the larger stars.

The rays of each star bend irregularly, and meet the rays of the spicules forming the neighbouring stars. The rays of the different spicules thus run along for some distance parallel to one another, and are held together by a layer of elastic sarcode, which invests all the spicules and all their branches. Between the rays of the spicules, over the whole surface, the sarcode forms an ultimate and very delicate network, its meshes defining minute inhalant pores.

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* The genus is named in compliment to M. Holten, Governor of the Faroe Islands; and the species is dedicated to Dr. W. B. Carpenter, V.P.R.S., with whom the author was associated in the conduct of the expedition. [A figure of the species is given at p. 120 of the present volume of the 'Annals.']

At the top of the sponge there is a large osculum, about 3″ in diameter, which terminates a cylindrical cavity, which passes down vertically into the substance of the sponge to a depth of 5″ 5‴. The walls of this oscular cavity are formed upon the same plan as the external wall of the sponge; and the stars, which are even more conspicuous than those of the outer wall, are due to the same arrangement of spicules of the same form. The ultimate sarcode network is absent between the rays of the stars of the oscular surface.

The sponge-substance, which is about 2″ in thickness between the oscular and the outer walls, is formed of a loose vacuolated arrangement of bands and rods of greyish consistent sarcode, containing minute disseminated granules and groups of granules of horny matter, and minute endoplasts.

Towards the outer wall of the sponge the sarcode trabeculæ are arranged more symmetrically, and at length they resolve themselves into distinct columns, which abut against and support the centres of the stars, leaving wide, open, anastomosing channels between them. The sarcode of the outer wall, and that of the wall of the oscular cavity, is loaded with minute spicules of two principal forms—quinqueradiate spicules with one ray prolonged and feathered, and minute amphidisci.

Over the lower third of the body of the sponge, fascicles of enormously long delicate siliceous spicules pass out from the sarcode columns of the sponge-body in which they originate, through the outer wall, to be diffused to a distance of not less than half a metre in the mud in which the sponge lives buried; and round the osculum and over the upper third of the sponge, sheaves of shorter and more rigid spicules project, forming a kind of fringe.

The author referred all the sponges which were found inhabiting the chalk-mud to the Order Porifera Vitrea, which he had defined in the 'Annals and Magazine of Natural History' for February 1868. This order is mainly characterized by the great variety and complexity of form of the spicules, which may apparently, with scarcely an exception, be referred to the sexradiate stellate type, a form of spicule which does not appear to occur in any other order of sponges. The genus *Holtenia* is nearly allied to *Hyalonema*, and seems to resemble it in its mode of occurrence. Both genera live imbedded in the soft upper layer of the chalk-mud, in which they are supported,—*Holtenia* by a delicate maze of siliceous fibres, which spread round it in all directions, increasing its surface without materially increasing its weight—*Hyalonema* by a more consistent coil of spicules, which penetrates the mud vertically and anchors itself in a firmer layer.

It appeared to the author and to Dr. Carpenter, who had had their attention specially directed to this point as bearing upon the continuity and identity of some portions of the present calcareous deposits of the Atlantic with the Cretaceous formation, that the vitreous sponges are more nearly allied to the *Ventriculites* of the chalk than to any recent order of Porifera. They are inclined to ascribe the absence of silica in many Ventriculites, and the absence of disseminated silica in the chalk generally, to some process, probably dialytic, subsequent to the deposit of the chalk, by which the silica has been removed and aggregated in amorphous masses, the chalk flints.

The Vitreous Sponges, along with the living Rhizopods and other Protozoa which enter largely into the composition of the upper layer of the chalk-mud, appear to be nourished by the absorption through the external surface of their bodies of the assimilable organic matter which exists in appreciable quantity in all sea-water, and which is derived from the life and death of marine animals and plants, and, in large quantity, from the water of tropical rivers. One principal function of this vast sheet of the lowest type of animal life, which probably extends over the whole of the warmer regions of the sea, may be to diminish the loss of organic matter by gradual decomposition, and to aid in maintaining in the ocean the "balance of organic nature."

"On *Palæocoryne*, a Genus of Tubularine Hydrozoa from the Carboniferous Formation." By Dr. P. Martin Duncan, F.R.S., Sec. Geol. Soc., and H. M. Jenkins, Esq., F.G.S.

Palæocoryne is a new genus containing two species, and belongs to a new family of the Tubularidæ. The forms described were discovered in the lower shales of the Ayrshire and Lanarkshire coal-field; and an examination of their structure determined them to belong to the Hydrozoa, and to be parasitic upon Fenestellæ. The genus has some characters in common with *Bimeria* (St. Wright), and the polypary is hard and ornamented. The discovery of the trophosome and probably part of the gonosome of a tubularine Hydrozoon in the Palæozoic strata brings the order into geological relation with the doubtful Sertularian Graptolites of the Silurian formation, and with the rare medusoids of the Solenhofen stone.

"On the Rhizopodal Fauna of the Deep Sea." By William B. Carpenter, M.D., V.P.R.S.

The author commences by referring to the knowledge of the Rhizopodal fauna of the Deep Sea which has been gradually acquired by the examination of specimens of the bottom brought up by the sounding-apparatus; and states that whilst this method of investigation has made known the vast extent and diffusion of Foraminiferal life at great depths—especially in the case of *Globigerina-mud*, which has been proved to cover a large part of the bottom of the North Atlantic Ocean—it has not added any new generic types to those discoverable in comparatively shallow waters. With the exception of a few forms, which, like *Globigerina*, find their most congenial home, and attain their greatest development, at great depths, the general rule has seemed to be that *Foraminifera* are progressively dwarfed in proportion to increase of depth, as they are by a change from a warmer to a colder climate—those which are brought up from great depths in the Equatorial region bearing a much stronger resemblance to those of the colder temperate, or even of the Arctic seas, than to the littoral forms of their own region.

The author then refers to the recent researches of Prof. Huxley upon the indefinite protoplasmic expansion which he names *Bathybius*, and which seems to extend itself over the ocean-bottom under great varieties of depth and temperature, as among the most important of the results obtained by the sounding-apparatus.

By the recent extension of dredging-operations, however, to depths previously considered beyond their reach, very important additions have been made to the Foraminiferal fauna of the Deep Sea. Several new generic types have been discovered, and new and remarkable varieties of types previously known have presented themselves. It is not a little curious that all the *new* types belong to the Family LITUOLIDA (consisting of Foraminifera which do not form a calcareous shell, but construct a "test" by the agglutination of sand-grains), which was first constituted as a distinct group in the author's 'Introduction to the Study of the Foraminifera' (1862). The first set of specimens described seem referable to the genus *Proteonina* of Prof. Williamson; but the test, instead of being composed (as in his specimens) of sand-grains, is constructed of sponge-spicules, cemented together with great regularity, so as to form tubes, which are either fusiform or cylindrical, being in the former case usually more or less curved, and in the latter generally straight. Of the genus *Trochammina* (Parker and Jones) many examples were found of considerable size, resembling Nodosarians in their free moniliform growth, but having their tests constructed of sand-grains very firmly cemented together, with an intermixture of fragments of sponge-spicules, which give a hispid character to the surface.—The genus *Rhabdammina* of Prof. Sars is based on a species (the *R. abyssorum*) first obtained in his son's dredgings, of which the test is very regularly triradiate, sometimes quadriradiate, and is composed of sand-grains very regularly arranged, and firmly united by a ferruginous cement. Not only was this type represented by numerous specimens in the 'Lightning' dredgings, but another yet more considerable collection was formed of irregularly radiating and branching tubes, which are composed of an admixture of sand-grains and sponge-spicules, united by ferruginous cement. These seem to originate in a "primordial chamber" of the same material, which extends itself into a tube that afterwards branches indefinitely. This type may be designated *R. irregularis*.—Of the protean genus *Lituola* (Lamarck) a large form was met with which bears a strong resemblance to the *L. Soldani* of the Sienna Tertiaries. Its nearly cylindrical test is composed of sand-grains very loosely aggregated together, forming a thick wall; and its cavity is divided by septa of the same material into a succession of chambers, arranged in rectilineal series, each having a central orifice prolonged into a short tube. The genus *Astrorhiza*, instituted a few years ago by Dr. O. Sandahl, was represented by a wide range of forms, referable to two principal types (the one an oblate spheroid, with irregular radiating prolongations, the other more resembling a stag's horn, with numerous digitations), passing into one another by insensible gradations. The composition of its thick arenaceous test is exactly the same as that of the test of the *Lituola* found on the same bottom; but its cavity is undivided; and there is no proper orifice, the pseudopodial extensions having apparently found their way out between the sand-grains that formed the termination of the radiating extensions or digitations. The genus *Saccammina* (Sars) is characterized by a very regular spherical test, built up of large angular sand-grains strongly united by ferruginous cement, which are so arranged as to form a wall-surface well smoothed off externally, whilst its interior is roughened by their angular projections. The cavity is undivided, and is furnished with a single orifice, which is surrounded by a tubular prolongation of the test, giving to the whole the aspect of a globular flask.

The family MILIOLIDA, consisting of porcellanous-shelled Foraminifera, was represented at the depth of 530 fathoms by a *Cornuspira foliacea* of extraordinary size, and at the depth of 650 fathoms by a series of *Biloculinæ* of dimensions not elsewhere seen except in tropical or subtropical regions.

Of the family GLOBIGERINIDA a considerable number of forms presented themselves; but, with the exception of the ordinary *Globigerina* and *Orbulina*, these were not remarkable either for number or size. The *Globigerina*-mud brought up in large masses by the Dredge, exhibited the same composition as had been previously determined by the examination of Soundings; but it included a large amount of animal life of higher types, whilst it seemed everywhere permeated by the protoplasmic *Bathybius* of Huxley, as described in the author's "Preliminary Report." The *Globigerinæ* vary enormously in size; and the author gives reason for the belief that this variation is not altogether the result of growth, but that many small as well as large individuals have (speaking generally) attained their full dimensions. He describes the sarcodic body obtained by the decalcification of the shell, and discusses the question whether (as some suppose) *Orbulina* is the reproductive segment of *Globigerina*, as to which he inclines to a negative conclusion. He describes the curious manner in which the shells of *Globigerinæ* are worked-up into cases for Tubicolar Annelids; of which cases several different types presented themselves, the Foraminiferal shells in some of them being combined with sponge-spicules. A remarkably fine specimen of *Textularia* was met with alive, of which the porous shell was encased by sand-grains; this being laid open by section showed the sarcodic body of an olive-greenish hue, corresponding with that of the *Lituolæ* and *Astrorhizæ* also found alive. Several Rotaline types presented themselves sparingly in the *Globigerina*-mud; these are specially characteristic of the Cretaceous Formation.

The family **Lagenida** was represented not merely by its smaller forms, but also by a large and beautiful living *Cristellaria*, that closely corresponds with one of the forms described by Fichtel and Moll from the Siennese Tertiaries, whilst even exceeding it in dimensions.

These results conclusively show that reduction in the size of *Foraminifera* cannot be attributed to increase of pressure, since the examples of *Cornuspira*, *Biloculina*, and *Cristellaria* found at depths exceeding 500 fathoms were *far larger* than any that are known to exist in the shallower waters of the colder temperate zone. But as these all occurred in the *warm area*, whose bottom-temperature indicates a movement of water from the Equatorial towards the Polar region, it is probable that their size is related to the *temperature* of their habitat, which is found to be in like relation to the general character of the fauna of which they formed part. On the other hand, as we now know that the climate of the deepest parts of the ocean-bottom, even in Equatorial regions, has often (if not universally) Arctic coldness, the dwarfing of the abyssal *Foraminifera* of those regions is fully accounted for on the same principle.

Besides these examples of new or remarkable forms of *Foraminifera*, the 'Lightning' dredgings yielded some peculiar bodies, the examination of which would seem to throw light upon the obscure question of the mode of reproduction in this group. One set of these are cysts, of various shapes and sizes, composed of sand-grains loosely aggregated (as in the tests of *Lituola* and *Astrorhiza*), which, when broken open, are found to be filled with aggregations of minute yellow spherules, not enclosed in any distinct envelope. These are supposed by the author to be *reproductive gemmules* formed by the segmentation of the sarcodic body of a Rhizopod, in the same manner as "zoospores" are formed in Protophytes by the segmentation of their endochrome. Of such segmentation he formerly described indications in the sarcodic body of *Orbitolites*; and corresponding phenomena have been witnessed by Prof. Max Schulze. But in another set of cysts, of similar materials but of firmer structure, bodies are found having all the characters of *ova*, with *embryos* in various stages of development. In none of these, however, does the embryo present characters sufficiently distinctive to enable its nature to be determined; and the hypothesis of the Foraminiferal origin of these bodies chiefly rests upon the conformity in the structure of the wall of the cysts with that of the tests of *Lituola* and *Astrorhiza*, and upon the improbability that such cysts should have been constructed by animals of any higher type.